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GEM Cost Estimating Plan (DRAFT)

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Abstract:

This document describes the format and procedures to be used to develop the GEM cost estimate. This is intended to be the document which instructs the GEM "subsystem engineers" in their responsibilities for the cost estimate. The Work Breakdown Structure (WBS) is defined as the highest levels and guidelines are given for completing it at lower levels by subsystem. Then the matrix to be used for accumulating the cost estimate is explained in detail. Labor rates and the procedure for setting contingencies are then described. Finally, the overall (short!) schedule for the cost estimate effort is given.

DRAFT

GEM
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1.0 Scope

The GEM collaboration will produce a comprehensive and detailed estimate for the cost of the development and construction of a large, high p_T detector at the SSC site. This cost estimating plan (CEP) defines the guidelines and methodology that will be used during the entire cost estimating process. Since GEM is truly an international collaboration of many participants spanning a broad spectrum of resources from numerous universities and laboratories around the world, clear guidance is required from the beginning to assure that the final product is complete and consistent. All participants shall perform their work in full compliance with this CEP. Any changes required shall be amended to this plan only after approval from the GEM project management.

2.0 Objectives

2.1 The primary cost estimating objective is to develop a comprehensive estimate of the total GEM project cost. This includes costs for the necessary research and development activities as well as for the engineering, design, analysis, procurement, fabrication, assembly, installation, start-up and management of the construction project itself. Contributions of all collaborating institutions shall be included and implemented in consistent content and format. Costs shall be accumulated starting from the beginning of the project, defined to be the beginning of fiscal year 1991, to the completion of the project, defined to be the commencement of experimental activities. All costs will be tabulated into a single computer data base. The subsystem databases will be generated by each subsystem cost estimator but coordinated into a master data base by the cost estimating manager.

2.2 During the cost estimating process it is desired to develop the detailed backup information that will justify all estimates and provide confidence to reviewing organizations that the costs are reasonable. Vendor quotations, engineering calculations, drawings, similarities to other systems and other pertinent data will be collected and organized into individual subsystem cost books. In addition basic subsystem configuration will be defined along with a list of critical assumptions made during the estimating process.

These books will be generated according to the guidelines established in this plan and be available for review.

2.3 Projects of the size, complexity and challenge of GEM will have some uncertainty and cost risk. Estimates are being made prior to having any final designs and include projections of expected development and engineering tasks. Thus, contingency allotments will be generated to account for these uncertainties. The subsystem estimators will perform standardized risk/contingency analyses to develop a consistent justification for all contingency costs which are included in the total system cost. These analyses will be performed according to the guideline established in this CEP.

2.4 The costs of the GEM detector will be monitored and must be controlled over the life of the project. This plan will guide the development of a data base that can provide the basis for this task. The two dimensional system/task hierarchy used in the CEP establishes costs in a format that can be translated to a formalized planning system. That system can be implemented to track the actual incurred cost against the projected cost estimates It is thus vital that the guidelines established by this CEP be strictly followed so that subsequent project monitoring activities may be facilitated.

3.0 Basis

3.1 The basis for the cost estimate developed according to this CEP will be a detailed bottom-up estimate for each subsystem. These estimates shall be based on FY 92 dollars. Escalation factors will be applied at the top level by the CEP coordinator using the temporal cost distributions defined by the subsystem estimators.

3.2 Cost estimates will be developed according to a preapproved two dimension cost matrix, shown in Table 1, that will be based on a system wide Work Breakdown Structure (WBS). The vertical dimension of the matrix will be the WBS hierarchy which delineates all subsystems and divides each of those into multiple levels of daughter subsystems. The horizontal dimension of the matrix defines the labor and material required in each of five functional activities for each WBS element. These activities are engineering/design, inspection/administration, procurement/fabrication, assembly and installation.

3.3 In addition to providing cost matrix information each estimator shall develop his/her own cost book. This document shall contain supporting information which substantiates each cost data item. This information will be used during both the internal and external defense of the system costs.

4.0 Work Breakdown Structure

The WBS is a hierarchy of elements which identifies all components of a system and their mother/daughter relationships. Costs for all systems and activities will be accumulated in a single WBS list. Cost estimators will develop the subsystem WBS hierarchies which will be collected and collated into the GEM detector WBS.

4.1 Level 1 and 2

The guideline WBS hierarchy is listed in Table 2. The numbering scheme is consistent with the structure file listing used by SSCL for the entire project. The top level elements are listed below:

522. GEM	level 1
522.5 Physics Research	
522.50 Construction	level 2
522.51 Research and Development	level 2
522.52 Conceptual/Preliminary Design	level 2

The first four digits are common to all GEM subelements. Therefore, for reasons of simplicity they will not be explicitly utilized in the GEM WBS. Instead the subsystem estimators will use the following level 2 nomenclature:

0 Construction	level 2
1 Research and Development	level 2
2 Conceptual/Preliminary Design I	level 2

4.1.1 The construction WBS element consumes the bulk of the GEM project costs. It includes all engineering activities between the Technical Design Report (TDR) and project completion. All engineering, analysis, design, procurement, fabrication, assembly and installation costs are accumulated under this element. Facility, utility and subsystem project management costs that are unique to a particular subsystem are included under that subsystem's WBS element.

4.1.2 Research and development tasks are those engineering and scientific tasks that are performed to advance the technical approach of a particular subsystem or demonstrate the feasibility of a new concept. They can be analytical or experimental in nature. After a particular design concept is baselined and approved by SSCL at the TDR all future development activities are considered part of the construction project unless they advance the state of the art of that design. Costs for R&D will clearly be heaviest in the early phase of the project and declining rapidly after the TDR process is complete.

4.1.3 Conceptual/ preliminary design activities include all engineering design tasks from the time when the Letter of Intent (LOI) is accepted to the TDR. Analysis, tradeoffs studies, design engineering, planning, and costing activities that are exercised to establish a baseline conceptual design are part of this WBS level.

4.1.4 Multiple options exist for some of the GEM subsystems. These options will be explicitly identified in lower level elements. Redundant level 2 entries will be developed as necessary to identify the costs of different combinations of options. For example, two construction level WBS elements will be generated, one for each of the two muon systems under consideration.

4.2 Level 3

4.2.1 Each of the three level 2 items will have eight subelements corresponding to the eight major subsystems of the GEM project. These are

- x1 Central Tracker
- x2 Calorimetry
  - x2.1 Liquid Argon calorimeter
  - x2.2 Forward Calorimeter
  - x2.3 Pre Radiator
  - x2.4 Hadron Calorimeter
  - x2.5 Electromagnetic Calorimeter
- x3 Muon subsystem
  - x3.1 PDT
  - x3.2 LSDT

x4 Magnet subsystem
x5 Electronic subsystem
x6 Computers and Control
x7 Interface systems
x8 Project Management

x = level 2 designator (0,1 or 2)

4.2.1.1 Construction costs for the central tracker shall include the inner and outer tracker, structures, alignment system, cooling systems, assembly, test and installation equipment, and other ancillary support equipment. Electronic channel costs for the inner tracker shall also be included for all hardware up to the receiver/buffer boards. Outer tracker channel costs shall not be included in this subelement. The electronic subsystem shall cover these costs which begin with the preamplifier located in the detector.

4.2.1.2 The calorimetry element shall identify costs for the liquid argon calorimeter, the forward calorimeter, and preradiator and optional costs for the barium flouride electromagnetic calorimeter and scintillating fiber hadron calorimeter. Costs shall include detector components, structures, cooling systems, cryogenics, assembly,test and installation equipment, and sensing electronics. Electronic channel costs shall be covered in the electronic systems WBS element. Channel costs begin with the preamplifier located in the detector. Assembly facilities at SSC not provided by SSC shall also be included.

4.2.1.3 Two muon system options exist. The WBS structure shall accommodate both the pressurized drift tube and limited streamer drift tube options. Costs shall include the chambers, support structure, central and endcap assemblies, gas supply system, cooling system, resistive plate chambers, high voltage electronics, sense electronics, and assembly, test and installation equipment. Electronic channel costs, which begin with the preamplifier located in the detector, are included in the electronic systems WBS element.

4.2.1.4 The magnet subsystem shall include all costs for the coil assemblies, endpoles, structures, vacuum system, thermal control, cryogenics, power systems, sense and control electronics up to the slow control workstations, and assembly, test and installation

equipment. The central membrane which supports the tracker and calorimeter, the forward calorimeter support structure and the steel interface structure between the magnet vacuum vessel and the SSC provided concrete foundation is a part of this WBS element.

4.2.1.5 The electronic subsystem shall include trigger and data acquisition as well as electronic channel costs for all of the detectors except for the inner central tracker. The triggering system includes all electronics for the level 1 and level 2 triggers for the muon, calorimeters, central tracker and all global triggering systems. This includes all optical links, racks, circuit boards, crates and ancillary electronic equipment. Channel design varies from subsystem to subsystem but in general includes cabling, optical fiber links, high and low voltage power supplies, integrated circuits, PC boards, preamplifiers, racks, and crates with power and controllers. Costs included in this subsystem generally begin with the preamplifier located after the sensing electronics and ends at the fiber termination in the Operations Center.

4.2.1.6 The computers and control subsystem shall provide "slow" control for total detector operation, Level 3 filter computational capability and an online computer network with local data storage. Slow control equipment includes computer workstations, DAQ crates located at the subsystems and connecting links (sensors, actuators, and DAQ modules are costed under each detector subsystem), TV network, UPS, system software and computer support equipment. Level 3 filter costs are dominated by the array of central processing units required but also include workstations, file server, racks/cabinets, software and networking equipment. Off-line computational capability and long-term tape storage are assumed to be costed by SSCL. Also, all TV cameras, recorders, switching equipment and communication systems shall be included.

4.2.1.7 Interface systems are facilities, installation equipment and non-standard utilities that are not provided by SSCL. They are not subsystem specific and are used by the collaboration as a whole. Items that are required for a single subsystem are listed under that subsystem WBS element. Examples of interface systems are compressed air systems, scaffolding, installation fixturing, transport systems, non-conventional cooling, detector emergency power, and detector safety systems.

4.2.1.8 Project management encompasses all administrative and management efforts required to direct the GEM project through completion. This includes management personnel and technical staff, system engineering, resource management, safety, and QA personnel, ancillary support contracts, travel, and supplies and expenses. Global analyses that assess technical issues of multiple subsystems shall also be included in this WBS element. Costs that are required to manage the detector project as a whole are included here. Subsystem management costs are defined at the subsystem level.

4.3 Level 4 and below

4.3.1 Levels at 4 and below will be defined by each subsystem estimator as required. In general most subsystems should be listed down to level 6 or 7 to provide sufficient detail for a meaningful estimate. At this final level costs should be in the 100K$ to 500k$ range in most cases.

4.3.2 Each level 3 element shall be subdivided into its logical subsystem components. The last subelement at this level shall be subsystem project management as shown below.

xx.1 Subsystem component 1
xx.2 Subsystem component 2
.
.
xx.n Subsystem component n
xx.n+1 Subsystem project management
- xx.n+1.1 Project management and administration
- xx.n+1.2 Resource management
- xx.n+1.3 ES&H
- xx.n+1.4 Quality assurance
- xx.n+1.5 System integration

4.3.3 Subsystem project management includes manpower for planning and control, Group or Division administrative personnel including supervisors and clerical support. ES&H and QA planning and controls, meetings, travel, reviews, developing plans and controls for detector subsystems and facility interfaces are also included. Procurement costs must identify office supplies, engineering service equipment and operating charges.

4.3.4 Interface Systems and Project Management will not be subdivided into the previously listed level 4 subsystems since they are global efforts that are common to all subsystems. Instead they are subdivided as follows:

x7	Interface systems	level 3
	x7.1 Experimental hall	level 4
	x7.2 Surface facilities	
	x7.3 Process utilities	
	x7.4 Safety systems	
x8	Project Management	level 3
	x8.1 Administration	level 4
	x8.2 Resource management	
	x8.3 Environment, Safety and Health	
	x8.4 Quality Assurance	
	x8.5 System Integration	

5.0 Cost Matrix

5.1 The cost matrix is the data set that will collect all information for the GEM cost estimate. All data will be input by each subsystem estimator in a format described below using an EXCEL 3.0 computer spreadsheet. Each of the subsystem data bases will be compiled into a single spreadsheet that will be used to calculate total system costs and provide a mechanism for system-wide data analysis.

5.2 Tables 3 and 4 show that the cost matrix is actually divided into two separate data sets, a cost table (CT) and a supporting data table (SDT). The SDT shall be located in the EXCELL spreadsheet next to the CT and vertically synchronized with the CT so that the WBS elements line up horizontally. The table are presented separate from each other to maintain legibility of the printed information when displayed on a single standard sheet of paper.

5.2.1 The CT contains the basic cost information for the WBS elements. Material and labor costs are identified in each of 5 main functional categories: engineering/design, inspection/administration, procurement/fabrication, assembly, and integration. Costs are estimated in FY 91 dollars. Roll-ups of total costs from subelements to higher level elements are performed by equations imbedded in the EXCELL spreadsheet written by each subsystem estimator. Each estimator is responsible for assuring

that all roll-ups are properly implemented and accurate. Labor rates, material estimating strategies, and contingency methodology are defined in subsequent sections.

5.2.1.1 Engineering/design

5.2.1.1.1 *Engineering/design includes only labor for all engineering* design, engineering analysis, reliability analysis, design layout, and detailing and checking of fabrication drawings. Documentation for performance and fabrication specifications, safety analysis reports, design reviews, assembly procedures and testing or system checkout procedures are also included in this category.

5.2.1.1.2 *Materials and Supplies*
Material and supply costs cover all procurements required to support the EDIA activity in general. Material costs for travel, supplies and expenses, office and engineering service equipment and operating charges for that equipment are included.

5.2.1.1.3 Inspection/Administration
Inspection/Administration collects all labor costs to administer fabrication and procurement contracts, scheduling of production, production inspection, pre and post assembly inspection of individual components of the detector subsystem. Also included is engineering administration labor associated with supervising both on-site and off-site assembly, installation and system checkout. Quality assurance planning, inspection, oversight, and documentation costs are also accumulated in this category. In addition, this functional category collects all costs associated with administering the project at either the subsystem or detector level. This includes project management, scheduling, planning, costing, and activities associated with implementing ES&H requirements.

5.2.1.1.4 Procurement/fabrication
Procurement/fabrication includes procured costs for detector component material, fabrication, tooling, and equipment, necessary to construct the GEM detector and supporting facilities. Purchased labor contracts to perform tasks associated with engineering, installation, or assembly are not included in this category but rather in the specific category that they are associated with.

5.2.1.1.5 Assembly

Assembly includes labor and material necessary to assemble the purchased and fabricated components into subassemblies. These activities may occur at both off-site and above ground SSC facilities. Tasks also include alignment, checkout and test necessary to verify that assembled components satisfy subsystem requirements. Fixturing, handling equipment and test equipment are included in this category. Supervision and inspection of the activities performed in this category are specified in EDI/QA.

5.2.1.1.6 Installation covers all activities performed by the GEM collaboration in the experiment hall. This includes transporting the equipment to the downhole location, rigging, erection, assembly, alignment, integration,test, checkout and startup of the entire GEM detector. Costs in this category begin to accrue when the physical equipment enters the experiment hall. and ends after the initial startup of the detector prior to commencement of experimental activities. All equipment necessary to perform these functions must be included.

5.2.1.1.7 Contingency
Contingency for the GEM detector cost estimate shall be based on a standardized risk analysis. Each estimator shall perform the risk analysis identified in Section 8.0 and enter the associated contingency in the CT. Depending upon the particular subsystem being analyzed contingency may be applied at the lowest WBS level or at a higher subassembly level. It is the responsibility of the estimator to make this determination. In any case, the estimators are responsible for assuring that each and every component has appropriate and defensible contingencies applied.

5.2.2 Support Data Table
The SDT, which is divided into two matrixes (Table 4a and 4b), provides important supporting data to the cost estimates. Estimators are required to provide all input in this table as well as the CT. The information contained in the SDT is essential for interpreting the cost estimates, defending them and temporally distributing the costs to permit accurate cost projections to the end of the project. Data columns for this table, shown in Table 4, are defined below.

5.2.2.1 No./units
The number and units columns identify the basic cost unit that was used to determine the cost and the total number of the units that

was assumed. Typical values used for units are tons, meters^2, channels, system, assembly, and fibers. Almost anything can be used but the more descriptive it is the more helpful it will be to a reviewer.

5.2.2.2 Estimate type

Each WBS element shall be tagged with a cost basis descriptor which characterizes the type of estimate that was used. Acceptable data entries are as follows:

1) Bottom-up (BU)
2) Specific analogy (SA)
3) Parametric study (PS)
4) Review and update (RU)
5) Trend analysis (TA)
6) Expert opinion (EO)

Definition of these categories can be found in DOE 4700.1, Project Management System.

5.2.2.3 Risk factors

The risk analysis described in Section 8.0 is used to calculate contingency. In the three columns provided in the SDT, technical, cost and schedule risk factors are input. Standard ranges for these parameters are 1 to 15 for technical and cost risk, 2 to 8 for schedule risk. In some cases the standardized risk parameters may not be appropriate. Higher values may be used as described in Section 8.

5.2.2.4 Risk percentages

The applied risk percentages are dependent on two factors. The first is whether the risk is associated with technical, cost or schedule concerns. The second is whether these concerns involve design, manufacturing, material cost or labor rate uncertainties. Acceptable value which range from 1% to 4% are defined in Section 8. These percentages are multiplied by the corresponding risk factor to determine the total contingency which should be applied.

5.2.2.5 Contingency total

This parameter is the sum of the products of the individual risk factors and corresponding risk percentages.

5.2.2.6 Dates

Start dates and completion dates for activities must be assigned to permit appropriate application of escalation factors to the base cost estimates. The month and year (numerical) shall be identified for the end dates in the five main functional categories, engineering/design, inspection/administration, procurement/fabrication, assembly and installation. In general this information shall be provided down to the lowest WBS elements. However, in some cases, lower level activities may be so detailed that identifying specific timelines for them becomes unreasonable or adds no further meaningful information. In these cases the subsystem estimators may decide to limit data entries to higher WBS levels. Project Management shall make the final determination.

6.0 Labor rates

6.1 Estimators shall use their best discretion in selecting the labor rates that should be used for their GEM cost estimates. In making their decision, the estimators should determine where the work shall be performed and use the most accurate information available regarding the labor rates for that particular institution. Detailed backup information shall be provided in the cost book supporting any non-standard labor rate used. Rates used shall be fully burdened with all associated costs.

6.2 In many cases the exact source of labor will not be known. In these cases standard labor rates are provided below and should be used selectively as required. These annual rates assume that 1794 hours are worked in a year. If cost estimates assumed a 100% effort factor and that all 2080 working hours are worked then these rates must be scaled up by 1.159.

6.2.1 National Laboratories

It is anticipated that the US National Laboratories will participate in many of the GEM subsystems. The following rates are average rates that may be used for work performed for any of these institutions. These rates include general overhead, support, payroll burden and general laboratory taxes.

Type	Rate (k$/yr)
Manager	233
Secretary	69
Engineer/physicist	161
Designer/coordinator	118
Senior technician	118

Junior technician	108
Craft	84

6.2.2 National average rates

National average rates may be used for cases where the source of labor is completely unknown.

Type	Rate ($/hr)	Rate (k$/y)
Executive Management	85.05	153
Prof Specialist/Tech Eng	65.91	118
Fac Spt/Supvsr/Foreman	34.55	62
Precision Production	41.99	75
Average Shop Machinist, Electrician, Technician	27.11	49

6.2.3 SSC employees

Work performed by SSC employees shall be charged at the following rates which are fully burdened.

Type	Rate ($/hr)	Rate (k$/y)
Manager	65.43	117
Engineer/physicist	38.38	69
Analyst/administration	24.59	44
Senior technician	24.59	44
Technician/draftsman	18.36	33
Clerks	14.11	25

6.2.4 Job/shop in Dallas area

Type	Rate ($/hr)	Rate (k$/y)
Engineer/physicist	49.97	90
Software engineer	49.97	90
Draftsman	27.75	50
Junior technician	19.14	34
Senior technician	26.58	48
Average machinist	31.89	57
Precision machinist	41.46	74

6.2.5 Contractor installation

For installation of equipment at the SSC site in Texas the appropriate Davis-Bacon wage rates are as follows. Rates are fully burdened.

Type	Rate ($/hr)	Rate (k$/y)
Crane operator	28.32	51
Rigger	25.81	46
Laborer	14.06	25
Millwright	23.76	43
Electrician	31.74	57
Welder	25.81	46
Pipefitter	22.86	41
Carpenter	23.76	43
Painter	16.28	29

7.0 Material costs

7.1 Material costs shall include all hardware costs for the entire GEM project. WBS elements shall be listed to cover projected requirements for each subsystem. All costs shall be based on FY 1992 dollars and shall have backup details included in the subsystem cost books.

7.2 Material costs include all procurement and fabrication for all GEM assemblies and facilities. This includes detector hardware, equipment, fixturing, tooling, utilities, test equipment, assembly equipment, computer hardware, raw material, and material processing.

7.3 Detector costs must also include facility and utility costs not provided by SSCL. These include, but are not limited to, gas systems, access and structures in the experimental hall and surface facilities, non-conventional cooling, power distribution exceeding the baseline, and emergency power. Safety systems costed by GEM include fire extinguishing systems, fluid spill control system, radiation monitoring systems, oxygen deficiency system and nitrogen inerting system.

7.4 SSCL will cost the following facilities:

1) Underground detector facilities
   Collision hall, shafts and tunnels

Power and electrical cabling*
HVAC*
Cooling*
CPW
CHW
LCW
ICW

2) Surface facilities
On-site assembly buildings
Shaft headhouses
Utility buildings
Operations buildings
Storage areas/hardstands
General purpose machine shops
Power and electrical cabling, routing and distribution
HVAC
Cooling*
CPW
CHW
LCW
ICW

3) Site infrastructure
Roads
Parking
Water and waste water
IR power distribution

*but not internal distribution to and thru the detector.

8.0 Risk Analysis/Contingency

8.1 Risk analysis shall be performed for each WBS element. Results of this analysis will be related to a contingency which shall be listed for each WBS element. Risk analysis parameters shall be listed in the SDT; contingency values shall be listed in the CT. Risk analysis/contingency methodology shall, in general, comply with the SSCL recommended technique.

8.2 SSCL methodology
This method is based on estimator evaluation of technical, cost and schedule risk for every WBS element. For technical risk, the value

of 1 implies "normal industrial supplied off the shelf item" and 15 is reserved for components "way beyond the current state-of-the-art." For cost risk values, 1 is used to indicate "vendor quote or catalog price for a specific item" and 15 is used for estimates where no data is available. Schedule risk factors range from 2 to 8. The technical risk factor is multiplied by a risk percentage which is categorized below The resulting percentages are added together to establish the total contingency allocation for a particular WBS element. The minimum contingency percentage under this approach is 5% and the maximum is 98%.

Risk Factor Table

Risk factor	Technical	Cost	Schedule
1	Existing design and off-the-shelf hardware	Off the shelf or catalog item	not used
2	Minor modifications to an existing design	Vendor quote from established drawings	No schedule impact on any other item
3	Extensive modifications to an existing design	Vendor quote with some design sketches	not used
4	New design within established product line	In-house estimate for item within current product line	Delays completion of non-critical path subsystem item
6	New design different from established product line. Existing technology	In-house estimate for item with minimal company experience but related to existing capabilities	not used
8	New design. Requires some R&D development but does not advance the state-of-the-art	In-house estimate for item with minimal company experience and minimal in-house capability	Delays completion of critical path subsystem item

10	New design. Development of new technology which advances the state-of-the-art	Top down estimate from analogous programs	not used
15	New design way beyond the current state-of-the-art	Engineering judgement	not used

Risk Percentage table

	Condition	Risk percentage
Technical	Design or mfg concerns only	2%
	Design and mfg concerns	4%
Cost	Material cost or labor rate concern	1%
	Material and labor rate concern	2%
Schedule		1%

8.3 *Good judgement*

There may be special cases where the parameter limitations defined above are inappropriate. Some high risk elements may deserve contingencies greater than 98%. In these cases, at the discretion of the the estimator and the approval of the cost review team, higher values may be used. Justification for these cases must be provided in the estimator's subsystem cost book.

9.0 Escalation

Escalation factors will be applied to the base FY 1991 costs identified in each estimators cost table. Factors to be used will be supplied at a later date and will be implemented into the GEM detector cost by the cost coordinator. Subsystem estimators do not

need to take any action except to include activity start and end dates.

10.0 Subsystem Cost Books/Supporting Documentation

10.1 Each cost estimator shall provide a subsystem cost book. The books shall contain all information necessary to defend all data presented in the cost table. The cost books shall be available in preliminary form at the internal cost review and in final form at the time of the LOI presentation.

10.2 Minimum contents of the cost books are as follows:

1) Cost Table
2) Supporting Data Table
3) System description
   Brief narrative describing subsystem, performance, assumptions, and key technical issues
4) System drawings
   Top level assembly drawings which define system general configuration and interfaces with other subsystems
5) Parameter list
   List of key parameters (minimum of 20)which define the subsystem in sufficient detail to uniquely identify it to reviewers and to enable revision tracking of the design

11.0 Responsibilities

Cost estimating responsibilities are as follows:

Subsystem	Responsible person
Magnet subsystem	G. Deis
Muon subsystem	F. Nimblett
Hadron calorimeter subsystem	M. Rennich
Electromagnetic calorimeter subsystem	M. Rennich
Central tracker subsystem	R. Barber
Electronic systems	D. Marlow
Computers and Control	K. MacFarlan
Liquid Argon calorimeter	J. Coulon

Forward Calorimeter	J. Coulon
Pre-radiator	M. Rennich
Interface systems	C. Johnson
Project management	R. Fischer

12.0 Percentage calculations

14.1 Research and development, Engineering/Design/Inspection/ Administration (EDIA), and contingency are often presented in reports as a percentage of a base cost. For GEM, these percentages shall be calculated as defined below and shown in Table 5.

14.1.1 The base construction cost is the sum of the procurement/fabrication, assembly and installation costs. It is basically the cost of procuring, fabricating and installing the detector into the experimental hall.

14.1.2 EDIA costs are the engineering, design, inspection, administration, and material/supply costs to support the construction (WBS 522.50) and the conceptual/preliminary design (WBS 522.52) activities. EDIA percentage is this cost divided by the base construction cost.

14.1.3 Research and development (R&D) costs cover engineering, design, material/supply, inspection and administration expenses and are totaled in WBS element 522.51. R&D percentage is this cost divided by the base construction cost.

14.1.4 Contingency is applied to each line element in the WBS. When cited as a percentage it is determined by dividing the contingency by the base construction cost plus EDIA. R&D is not included in this calculation.

WBS No.	Item	Eng/Des Labor	EDIA Mat/Supply	Insp/ Admin Labor	Proc/Fab Material	Assembly Labor and Materials	Installation Labor and Material	Subtotal	Conting	Total

Table 1. GEM cost matrix

522 GEM Detector

522.5 Physics Research

(522.5 precedes all succeeding numbers)

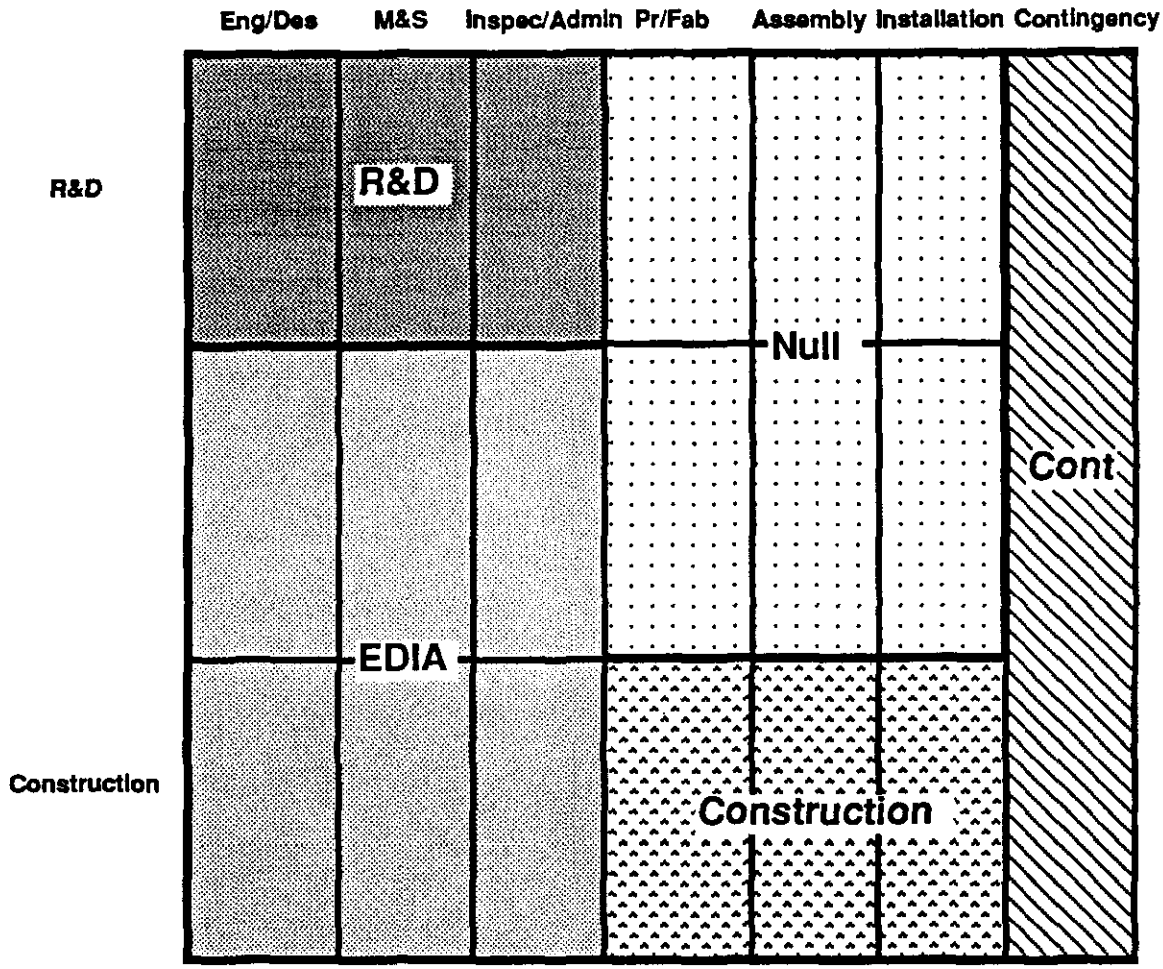
- 0 Construction
  - 01 Central Tracker
  - 02 Calorimetry
    - 02.1 Liquid Argon calorimeter
    - 02.2 Forward Calorimeter
    - 02.3 Pre Radiator
    - 02.4 Hadron Calorimeter
    - 02.5 Electromagnetic Calorimeter
  - 03 Muon subsystem
  - 04 Magnet subsystem
  - 05 Electronic subsystem
  - 06 Computers and Control
  - 07 Interface systems
  - 08 Project Management

- 1 Research and Development
  - 11 Central Tracker
  - 12 Calorimetry
    - 12.1 Liquid Argon calorimeter
    - 12.2 Forward Calorimeter
    - 12.3 Pre Radiator
    - 12.4 Hadron Calorimeter
    - 12.5 Electromagnetic Calorimeter
  - 13 Muon subsystem
  - 14 Magnet subsystem
  - 15 Electronic subsystem
  - 16 Computers and Control
  - 17 Interface systems
  - 18 Project Management

Table 2. GEM WBS hierarchy

- 2 Conceptual/Preliminary Design
  - 21 Central Tracker
  - 22 Calorimetry
    - 22.1 Liquid Argon calorimeter
    - 22.2 Forward Calorimeter
    - 22.3 Pre Radiator
    - 22.4 Hadron Calorimeter
    - 22.5 Electromagnetic Calorimeter
  - 23 Muon subsystem
  - 24 Magnet subsystem
  - 25 Electronic subsystem
  - 26 Computers and Control
  - 27 Interface systems
  - 28 Project Management

Table 2 (continued). GEM WBS hierarchy



$$\text{R\&D \%} = \frac{\text{R\&D}}{\text{Construction}}$$

$$\text{EDIA \%} = \frac{\text{EDIA}}{\text{Construction}}$$

$$\text{Contingency \%} = \frac{\text{Contingency}}{\text{Construction + EDIA}}$$

Table 5. Cost matrix components